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SOUTHERN CORRIDOR OF AQUATIC INVASIVE NETWORK – THE DANUBE RIVER PARADIGM

Momir PAUNOVIĆ*, Béla CSANYI**

A b s t r a c t. – The aim of this work is to highlight the importance of biological invasions (BI) in the Danube River Basin (DRB), to discuss the significance of the European Southern Invasive Corridor (the trajectory that links the Black and Northern Seas via the Danube River, Rhine–Main Canal and the Rhine river) for the BI process, as well as to summarize European legislation, standardisation and guidance documents related to invasive alien species (IAS). Recently, aquatic invasions have become an important issue. Non-indigenous species were recorded among all groups of aquatic organisms – algae, vascular plants, macroinvertebrates, fish and fish parasites. Parts of European inland waterways that are highly populated by non-native aquatic species are probably irreversibly changed with respect to their native biodiversity. BI can also cause different socio-economic consequences. In the case of the DRB, the International Commission for the Protection of the Danube River (ICPDR) acts as the coordinating body for multilateral and basin-wide actions related to water management, which involve resolving the issue of the IAS. Within the frame of the ICPDR activities, a risk assessment tool has been developed, as well as an approach to evaluate pressure caused by biological invasions for water bodies in the DRB. The list of alien aquatic taxa for the Danube River was prepared (three Cyanobacteria, seven algae species, 17 aquatic vascular plants, 51 aquatic macroinvertebrate and 32 fish species). Based on the Risk Assessment Procedure (the IAS–RAP–Danube) the "Black List" for the Danube River has been developed. The list includes 16 macroinvertebrate and ten fish and 13 aquatic macrophyte species. For the purpose of assessment of pressure caused by biological invasions, we are working on the development and testing of the Bioinvasion Assessment Index (BAI). The BAI is based

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on the assessment of a relative contribution of non-indigenous taxa to the analysed community. Based on the above, the DRB is specific and complex and it could be considered a scientific paradigm – a unique pattern, ideal model for study of BI phenomena.

Keywords: non-native aquatic taxa, invasive species, Danube River Basin, risk assessment, biological invasions, aquatic ecosystems

INTRODUCTION

Historical changes in the environment led to changes in the distribution of organisms, and those alterations have been accelerated by human influence. Pollution, hydro-morphological degradation, aquaculture, aquaristics, navigation, as well as other human activities strongly influence aquatic ecosystems. The influence of invasive alien species has been recognised as one of the major threats to native biodiversity [12].

The consequences of biological invasions (BI) are diverse and complex, since invaders can alter fundamental ecological properties such as dominant species in a community, productivity, nutrient cycling and can thus alter the structure and function of the ecosystem. The anthropogenic distribution of plants and animals is considered within the major threats to biodiversity [15]. Aquatic ecosystems are not an exception concerning this aspect of disturbance [2]. Ballast water of ships, fish stocking and aquaculture were pointed out as prospective agents of dispersal of non-indigenous species [10].

IAS has been recognized as one of the major threats to native biodiversity within the Danube River Basin (DRB) [12, 16, 17]. Canals can provide conduits for species to spread between previously separate biogeographic regions either by active movement, drift and/or as a result of ship transport [2]. After the construction of the Rhine–Main–Danube Canal, the Danube became an important invasion route. Several authors recorded the spread of non-indigenous species along the Danube (in both directions, upstream and downstream), as well as the expansion of neobiota from the Danube to its tributaries. The Danube River is a part of the so-called "Southern Invasion Corridor" and a part of the European Invasion Network [12, 10, 9].

The aim of this work is to point to the importance of BI in the DRB, to discuss the significance of the European Southern Invasive Corridor (trajectory that links the Black and Northern Seas via the Danube River, Rhine–Main Canal and Rhine river) for the BI process, as well as to summarize European legislative, standardisation and guidance documents related to IAS.

MATERIAL, METHODS AND STUDY AREA

The study of IAS in this paper is based on the results of the four international Danube surveys – Joint Danube Survey 1 – JDS1 [6], Joint Danube Survey 2 – JDS2 [7], Aquaterra Danube Survey – ADS [3] and Joint Danube Survey 3 – JDS3 [14].

For the purpose of collecting coherent data on the distribution of IAS within the DRB, the specific questionnaire was developed within the frame of the activities of the International Commission for the Protection of the Danube River (ICPDR), in order to collect additional information on the IAS in the Danube and its major tributaries. Based on the questionnaire, the data on non-indigenous algae, aquatic macrophytes, macroinvertebrates and fish distribution were collected. Besides the distribution data, the information on the origin, dispersal area, frequency of occurrence was provided, as well as the assessment of the level of invasiveness for listed non-indigenous taxa. The questionnaire included only the data on aquatic taxa, while the species that are not aquatic, but depend on water, were not considered.

In addition, the database on Alien Invasive Species within the Southern Invasive Corridor (AISSIC data base) has been used for the assessment. The AISSIC database has been developed at the University of Belgrade, Institute for Biological Research [13, 18] within the ALARM project (European Commission 6th Framework Programme Integrated Project ALARM, contract GOCE-CT-2003-506675). The database has been constantly maintained and currently it contains 4,100 records, with total of 129 alien and cryptogenic taxa covered (24 aquatic macrophytes, 71 macroinvertebrates, 26 fish, one amphibian and eight fish parasite species) within the Southern Invasive Corridor, which includes the main tributaries of the Danube, as well.

For the purpose of assessment of pressure caused by biological invasions on a particular assessment unit (it could be water body, part of water body, river stretch, whole river, lake, part of the lake, etc.) we are working on the development and testing of the Bioinvasion Assessment Index (BAI) [11]. The BAI is based on the assessment of a relative contribution to non-indigenous taxa to the analysed community. It also involves the value called "relative contribution" (pondering value) that reflects the assessed invasiveness of each alien species. The index is calculated based on a simple procedure:

$$BAI=(A1*RC1+A2*RC2\ldots Ai*RCi)/Ntot,$$

where A is relative abundance of i-th alien species, RCi is relative contribution of i-th alien species (or taxa) and Ntot is total abundance of analysed community (native+alien taxa) and it theoretically ranges from 0 to 1.

Altogether 2,580 km of the Danube River is covered by the data, including the mouths of 17 major tributaries.

RESULTS AND DISCUSSION

JDS1 in 2001 [6] confirmed that the building of the Main–Danube Canal and its opening in 1992 accelerated the migration of aquatic organisms in upstream and downstream direction. Among the aquatic macroinvertebrates collected during the JDS1 there are frequent and abundant neozoa species, which today already inhabit the Rhine river system. The JDS1 results emphasized the spreading of Ponto-Caspian crustaceans from the Lower Danube to the middle and upper stretch in particular Amphipoda species: *Dikerogammarus haemopbaphes, D. villosus, Obesogammarus obesus, Echinogammarustrichiatus, E. ischnus, Chelicorophium curvispinum*, the Mysidacea *Limnomysis benedeni, Hemimysis anomala*, and the Isopoda species *Jaeraistri* [12]. This confirmed the importance of the European Southern Invasive Corridor in recent migration of aquatic species.

The European Southern Invasive Corridor is a part of European inland water invasion network [10] – the complex system of navigable waterways and invasion corridors across the European continent.

In the case of the DRB, the International Commission for the Protection of the Danube River (ICPDR) acts as the coordinating body for multilateral and basin-wide actions related to water management, which involve the resolving of the IAS issue.

Within the frame of the ICPDR activities, considerable progress has been achieved in respect to understanding BI, developing the tool for risk assessment and assessment of pressure caused by biological invasions, as an indication related to this issue for the main water bodies within the DRB [11].

Based on the available data, three Cyanobacteria, seven algae species, 17 aquatic vascular plants, 51 aquatic macroinvertebrate and 32 fish species have been confirmed for the Danube River [11].

The number of non-native species recorded in period 2001–2013 is presented at Table 1. As seen in Table 1, the rise in the number of alien macroinvertebrate taxa over the period 2001–2013 is recorded. The number of non-native taxa within other biological quality elements is relatively constant over the same period.

Table 1. The number of non-native taxa recorded during the previous Danube surveys: JDS1 [6], Aquaterra Danube Survey (ADS – [3] and JDS2 [7] and JDS3 [12])

Quality element	JDS1 (2001)	ADS (2004)	JDS2 (2007)	JDS3 (2013)
Aquatic macrophytes	3	–	6	4
Macroinvertebrates	12	13	20	34
Fish	–	–	14	12

Based on the data of the Danube expeditions (JDS1 – [6], Aquaterra Danube Survey ADS – [3], JDS2 – [7] and JDS3 – [12]), six alien aquatic vascular plants were recorded.

Based on the JDS3 data [12], *V. spiralis* was the most abundant aquatic neophyte.

A considerable number of alien macroinvertebrate species were recorded in the upper and middle section of the Danube – 24 and 27 species, respectively. The problem comes from the fact that the majority of the species identified as non-native only for the upper (and probably the middle) section of the Danube are of Ponto-Caspian origin. Several species are considered native for the lower stretch of the Danube and thus, only seven non-native taxa were found for this Lower Danube section [12].

Among non-native macroinvertebrates, taxa of North American (4), Asian (4) of New Zealand (2) and Indo-Pacific (1) origin were identified. Spreading of Ponto-Caspian species from the Lower to the Middle and Upper Danube was found to be the most frequent case – 22 taxa of Ponto-Caspian original distribution were identified during the JDS3 [12].

Crustaceans of Ponto-Caspian origin *C. curvispinum, D. villosus* (Amphipoda) and *J. istri* (Isopoda), as well as molluscs species of Asian origin *C. fluminea* (Bivalvia) are the most abundant and frequent non-native macroinvertebrate taxa along the entire Danube. Thus, based on JDS3 data, mean abundance of *D. villosus* was 529 ind./m^2 for the Upper Danube and 431 ind./m^2 for the Middle Danube, while the abundance of *C. curvispinum* was 247 ind./m^2 for the Upper Danube and 310 ind./m^2 for the Middle Danube (both species native for the Lower Danube). It has to be emphasised that abundance values are estimated as average numbers based on the results of a different kind of macroinvertebrate samples (Multihabitat Sampling, Kick and Sweep and dredging).

Based on the Danube expeditions data and MA Questionnaire, a preliminary list of alien fish species for the Danube River has been prepared (Annex 4). Up to now, 29 alien fish species have been confirmed for the Danube River.

During the JDS3 [12], a total of 12 non-native fish species were recorded. Eight alien taxa were recorded for the Upper Danube, nine for the middle, while only four species that are non-native were identified in the lower section of the river. Based on the same dataset, fish species that are non-native for the Middle and Upper Danube of the Ponto-Caspian origin were the most numerous – five species. Additionally, the species of Asian (four taxa) and North American origin (three taxa) were recorded. According to the share of non-native species in total fish community abundance, the upper stretch of the Danube is exposed to higher pressure of biological invasions.

Within the frame of activities of the ICPDE, the proposal of the Risk Assessment Procedure (the IAS-RAP-Danube Risk Assessment Procedure) to be used for the DRB has been developed [11]. The IAS-RAP-Danube uses two sets of descriptors (species traits and assessed impact) and enables assessment of the level of invasiveness of each non-indigenous species. Based on applied risk assessment [11], the "Black List" for the Danube River has been developed. The list includes 16 macroinvertebrate and ten fish species. Besides, 13 aquatic macrophytes (six confirmed for the Danube, seven based on a list of invasive alien species of Union concern – Regulation of the European Parliament and of the Council, No 2016/1141; riparian vegetation that also comprises invasive non-native species was not taken into consideration).

Based on preliminary results of the testing of the Bioinvasion Assessment Index (BAI) [11], the Danube is under a considerable influence – the BAI index ranged from 0 at sites in the Upper Danube to 0.89 at the Middle Danube, with the mean value indicating a moderate level of biopollution. The pressure caused by biological invasions is higher in the Upper and Middle Danube compared to the lower stretch (downstream the Iron Gate sector). This situation is also indicated using other indexes – SBC [1, 8]. The SBC Index calculated based on the data for 2013 (JDS3) for macroinvertebrates and fish indicated moderate to high biocontamination (pressure caused by biological invasions), with a higher mean level for the Upper (high to severe biocontamination) and the Middle Danube (moderate to high biocontamination), in comparison to the Lower Danube (low biocontamination) [11].

Based on the calculation of the Biopollution Index BPL [8], the whole navigable stretch of the Danube River has been assessed as under a strong biopollution impact, with the final score of 3 [11].

The importance of the problem of BI is illustrated by the current activities on the EU level to provide an effective basis for dealing with the issue of the IAS. In that respect, the Regulation of the European Parliament and of the Council on the prevention and management of the introduction and spread

of invasive alien species was published (No 1143/2014, from 22 October 2014) with the idea to provide such platform.

CONCLUSIONS

Based on the above, the DRB is specific and complex, and could be considered a scientific paradigm – a unique pattern, ideal model for study of BI.

Recent researches confirmed that the Danube River is under the considerable pressure caused by the BI.

The most important element of the work to be done in the future is to collect reliable and high quality data on the distribution of the new alien taxa. In the field of scientific work, advanced sampling methods have to be used. An updated review of IAS is needed to summarize the state-of-the-art knowledge at the EU level.

It is of high importance to develop a methodology how to assess IAS in the frame of the EU WFD [4] compliant ecological status assessment. This issue includes the development of metrics that indicate the general impact caused by biological invasions, as well as clarifying the impact of this parameter on the ecological status assessment. More research is needed to properly deal with this issue.

Actions on the subject of the alien invasive species within the DRB have to be in line with related documents and activities on the EU level [5, 15].

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ЈУЖНИ КОРИДОР АКВАТИЧНЕ ИНВАЗИВНЕ МРЕЖЕ – ДУНАВСКА ПАРАДИГМА

Момир ПАУНОВИЋ, Бела ЧАЊИ

Р е з и м е

Сврха овог рада је да се истакне значај биолошких инвазија у сливу реке Дунав, размотри значај Европског јужног инвазивног коридора (путање која повезује Црно и Северно море преко Дунава, Канала Рајна – Мајна и реке Рајне) за процес биолошких инвазија. Поред тога, у раду се даје преглед европског законодавства, докумената за стандардизацију и смерница у вези са инвазивним страним врстама. Акватичке инвазије су недавно постале значајно питање. Алохтоне врсте забележене су међу свим групама акватичких организама – алги, васкуларних биљки, макроинвертебрата, риба и рибљих паразита. Делови европских унутрашњих водених путева који су густо насељени алохтоним акватичним врстама вероватно су неповратно измењени у погледу њиховог изворног биодиверзитета. Биолошка инвазија може такође изазвати различите социо-економске последице. Кад је реч о сливу Дунава, Међународна комисија за заштиту Дунава (*ICPDR*) наступа као координационо тело за мултилатералне активности и активности широм слива које се односе на водопривреду и тичу се решавања питања инвазивних страних врста. У оквиру активности Међународне комисије за заштиту Дунава, развијен је механизам процене ризика и приступ процене притиска који узрокују биолошке инвазије у водним телима у сливу Дунава. Израђен је списак страних акватичких таксона за Дунав (три цијанобактерије, седам врста алги, 17 акватичких васкуларних биљака, 51 акватички макроинвертебрат и 32 врсте риба). Путем поступка процене ризика (*IAS–RAP–Danube*), израђена је „Црна листа“ за Дунав. Листа садржи 16 макроинвертебрата, десет врста риба и 13 акватичких врста макрофита. У сврхе процене притиска који је узрокован биолошким инвазијама, радимо на изради и тестирању индекса процене биоинвазије (*Bioinvasion Assessment Index*). Индекс је заснован на процени релативног доприноса алохтоних таксона анализираној заједници. На основу горенаведеног, слив Дунава је специфичан и комплексан и може се сматрати научном парадигмом – реч је о јединственом обрасцу и идеалном моделу за проучавање феномена биолошких инвазија.

Кључне речи: алохтоне акватичке таксоне, инвазивне врсте, слив Дунава, процена ризика, биолошке инвазије, акватички екосистеми